Use of near infrared spectroscopy for the prediction of quality of poultry feeds in East Africa

Bastianelli, D. [a]; Fermet-Quinet, E. [b]; Davrieux, F. [c]; Friot, D. [a] and Hervouet, C. [a]

[a] *CIRAD, Laboratoire d'Alimentation Animale, TA 30/A Baillarguet, 34398 Montpellier Cedex 5, France. E-mail: denis.bastianelli@cirad.fr*

[b] *AU/IBAR/RALEA, P O Box 30786-00100, Nairobi, Kenya*

[c] *CIRAD, TA 80/16, 34398 Montpellier Cedex 5, France*

Keywords: poultry feed, chemical composition, nutritional value, quality control, near infrared spectroscopy

Introduction

A survey on the quality of poultry feeds was run in the east African countries of Kenya, Tanzania, Uganda, Ethiopia, Sudan, Eritrea and Burundi. The aim of the study was to provide a reliable overview of poultry feeds available on the local markets in order to advise farmers for feed use, and help feed millers to improve the quality of their products [1].

The first objective of the project was to obtain reliable data on the chemical composition and nutritional value of feeds available, in order to promote discussions between poultry farmers and feed manufacturers and to propose solutions for technical improvement of poultry production.

The second objective was to evaluate near infrared (NIR) spectroscopy as a simple, cheap and transferable analytical technique. Indeed, reliable laboratory analysis service is not always available locally. NIR spectroscopy calibrations of compound feeds and raw materials [2] have been developed for a long time [3] and exist throughout the world. They are however mainly developed by commercial companies and are therefore not available to small producers in developing countries [4]. Moreover, they are not always adapted to the low quality feeds available locally.

Materials and methods

Approximately 200 poultry feed samples were collected across the seven countries in order to cover the variability of all commercial feeds available for feeding to broilers and laying hens. The feeds, which originated from various suppliers and resellers, were collected during 2003 and 2004.

Chemical analyses of samples were performed on sets of 150 to 200 samples, depending on the particular analysis. The samples were selected for their spectral representation of the whole database based on clustering of neighbourhood distance calculated from principal components.

The analytical parameters measured were dry matter (DM), crude protein (CP), crude fat, crude fibre, starch and total mineral content (%). Metabolizable energy (ME) content ($kcal.kg^{-1}$) was calculated from the chemical composition [5]. DM content was measured following drying for 24 h at 103°C, CP content was measured by the Dumas combustion method, crude fat content was measured by soxhlet extraction after acid hydrolysis, crude fibre content was measured by the Wende method, starch content was measured by polarimetry and total mineral content was measured by overnight combustion at 550°C.

NIR spectral analysis was performed on the samples used for chemical analyses after they had been ground to pass through a 1 mm sieve. Spectra were collected in reflectance mode from two different cup fillings on a Foss 6500 spin cell instrument (Foss NIRSystems, Silver Spring, MD, USA) and the spectra for each sample averaged. Calibration equations were built after mathematical pre-processing of data using a standard normal variate (SNV) and detrend procedure on the second derivative of the spectra. Visible wavelengths were discarded because they introduced instability in

models with lower standard error of calibration (SEC) values but higher standard error of cross-validation (SECV) values. Partial least squares (PLS) regression was found to be the most efficient method for calibration. Data were processed with the modified PLS procedure of WinISI software (Win-ISI, Infrasoft International, Port Matilda, PA, USA). Reliability of prediction models was assessed by cross-validation with six subgroups resulting in the calculation of a SECV.

Results and discussion

Despite expected differences between broiler and layer feeds, there was no spectral gap between the two types of feed. The best calibrations were obtained incorporating data from all the feeds together. Prediction of most parameters was accurate (Table 1) with SECV values only 1 to 2 times greater than reference method repeatability. With the exception of total mineral content, the ratio of performance to deviation (RPD) (standard deviation divided by SECV) for all the other measured parameters ranged from 4 to 6. However the prediction for starch was less accurate with an SECV = 1.32 even if the RPD was high at 5.8 due to a high variability in the data set. This could be due to the fact that the starch comes mainly from maize by-products. As some samples only contained wheat by-products this may have lead to a biased prediction of starch content. Unlike protein or fibre, the value of starch content is not essential for feed characterization. It is however important in predicting ME content. Total mineral content also lacked precision with a SECV value of 1.86 which was much higher than the reference method resulting in a relatively low RPD of 2.6. This response is understandable since minerals do not respond in the NIR spectral region [4]. The prediction is therefore made "by default". The consequences are not important since the amount of total minerals is of little practical significance and is only used as an indicator.

Table 1. Performance of calibration models.

Constituent	Population			Calibration statistics			
	n	Mean	SD	SEC	R^2	SECV	RPD
Dry matter (%)	185	89.7	1.7	0.21	0.98	0.31	5.5
Crude protein (%)	182	17.1	2.6	0.44	0.97	0.62	4.2
Crude fat (%)	159	6.1	2.3	0.26	0.99	0.37	6.3
Crude fibre (%)	160	6.9	2.6	0.38	0.98	0.57	4.5
Starch (%)	152	32.7	7.7	1.00	0.98	1.32	5.8
Total minerals (%)	184	12.2	4.8	1.26	0.93	1.86	2.6
Meatabolizable energy ($kcal.kg^{-1}$)	134	2545	279	44	0.98	66	4.2

n: number of samples
SD: standard deviation
SEC: standard error of calibration
R^2: coefficient of determination of calibration
SECV: standard error of cross-validation
RPD: ratio of performance to deviation ($SD.SECV^{-1}$)

Following Dardenne *et al*. [6], it appeared to be more precise to calibrate ME calculated from reference chemical composition than to calibrate chemical composition and calculate ME from the predicted composition. The latter procedure leads to an accumulation of the errors made on each compound.

Figure 1 shows the result of predicting CP and ME content. The overall agreement was good, despite a few outlier values. These were not analytical outliers as the reference measurements were repeated. These outliers could be due to the fact that some feeds can be very different from one another due to the use of different raw materials. Nevertheless these "prediction outliers" were not "spectral outliers" and could not be routinely detected by their spectrum.

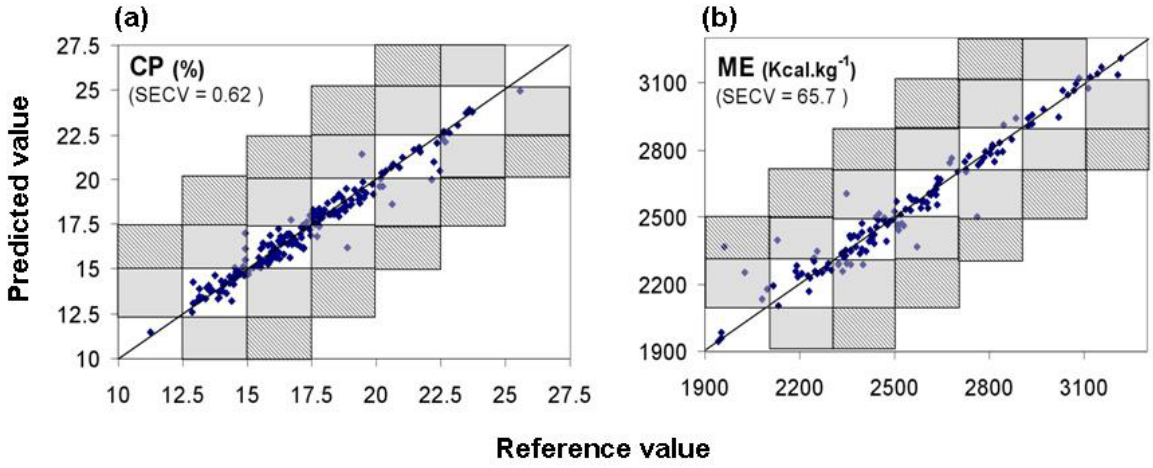

Figure 1. Prediction of (a) crude protein (CP) and (b) metabolisable energy (ME), and resulting assignment to categories. ☐ = matching category, ▩ = ± 1 category, ▨ = ± 2 categories.

In the context of small scale poultry production, it is more important to assign a feed to a category of quality than provide an exact value for its chemical composition. The ability of the predictions to enable feeds to be allocated to quality categories was also evaluated. The grid pattern in Figure 1 shows that the calibrations were successful in predicting seven quality categories for the CP and ME content of each sample. Within the set of assessed samples there were six outliers for CP and eight outliers for ME. With the exception of one prediction of ME, all the outliers were assigned to a neighbouring category, which is ± 1 category. This level of precision is acceptable in practice.

Conclusion

NIR spectroscopy models developed in this study are suitable to be used to predict chemical composition of poultry feeds in East Africa. The quality of predictions obtained with a limited set of approximately 200 calibration samples is probably linked to the relatively small number of raw materials used for feeds in this region. In general there are only 10 to 15 basic raw materials.

This survey showed that the quality of poultry feeds was generally very low [1]. As a consequence this increases the importance of quality control by farmers, or farmer's organizations, in a context where official quality control is very poor. The use of NIR spectroscopy in such conditions is very promising because chemistry laboratories are seldom available. NIR spectroscopy calibrations are currently being transferred to four local research centres.

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